

GPS/GIS Solutions for improving airfield inspections, reporting, maintenance and safety.

By:
Paul Cudmore
Eagle Integrated Solutions
Campbellford, Ontario, Canada
866-241-3264
paulc@team-eagle.ca

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Introduction

Airfield operations have increased in complexity and volume over the past several years due to a number of factors including but not limited to increased regulatory requirements, budget constraints, requirements for more take-offs/landings, training issues & losing experienced airfield operators (retirement for example). The Flight Safety Foundation [1] has indicated that as air traffic is on the rise, issues such as mitigating human error and training are critical to continuing to ensure safe working environments, not to mention the need to adopt new technologies to enhance safety & support an economically viable industry. As such, new tools & resources to help manage the workload and improve its efficiency, while maintaining and or enhancing safety, are appreciated by airport operators.

Background Information

Over the past decade, Global Positioning Systems (GPS) and Geographic Information Systems (GIS) technologies have advanced in terms of reliability, accuracy and cost-effectiveness. These technologies (see Appendix #1 for more detailed information) have become mainstream and are part of our daily lives in our personal vehicles, on our cellular phones and on the internet.

Because the GPS signal is free, it offers a very attractive solution for locating items and or tagging data to fixed items through easy to use graphical interfaces. Although there is a cost to the software and required hardware to utilize this technology, the main ingredient for extremely useful solutions is readily available for airports to take advantage of. "If a picture is worth a thousand words, then GIS is worth a million answers!" [2].

Airport Operators perspectives

From visiting with hundreds of airport operators the following observations have been noted in terms of areas of interest for GPS/GIS applications:

1. Increase situational awareness and help prevent incursions:

- a. This seems to be the number one concern with most airports
- b. Navigation and knowing where assets are during various weather events is very difficult
 - i. Vehicle operators need to know where they are and be better prepared for:
 - 1. Reduced visibility
 - 2. Reminders when inspectors are approaching restricted areas
 - a. Crossing a hold-line/stop-bar for example
 - b. Especially important for new staff & contractors on-site that don't know the airfield

2. Help with regulatory reporting:

- a. Preparing and executing audits and operations reviews continues to require a lot of management time and effort
- b. Airport Operators need to be able to demonstrate the required due diligence as the need arises

3. Minimize chemical usage and maximize its effectiveness:

- a. More effectively apply runway chemicals based on better micro data
- b. Evaluate chemical deployment and improve its usage
- c. Environmental concerns- demonstrate due diligence/appropriate use

4. Training:

- a. It can take months for an inspector/operator to become familiar with the airfield and effective in their duties.

5. Management oversight/reporting:

- a. It is difficult for management to be assured that the required areas were actually inspected/repaired/cleared. If so, when and by whom?
- b. Managers also wanted to see where vehicles were and what operations took place yesterday, last night etc.
- c. Managers want information at their finger tips, both in tabular format and graphically

6. Tracking chronic problems and critical issues:

- a. The traditional paper-based system does not allow a manager or inspector to “see” problems in a graphical way, or be able to query a database for re-occurring problems. They can’t identify trends & don’t receive preset warnings in order to let them to let them know of a chronic problem.

7. Link to the maintenance process:

- a. Managers want an electronic file to record the inspection work and link it to the work-order tasking and recording process used by the repair crew. This would provide the ability to track and follow-up on problems identified by the inspectors and ensure that identified problems get fixed when they are supposed to.

8. Efficiency:

- There is a need to complete required tasks more effectively (and safely)

GPS/GIS solutions to address the above issues are available today. These have been broken out in several broad operational categories:

Inspections/collection of data

Providing an electronic version of a normally existing airfield inspection (daily 139 inspection for example) is extremely powerful as handwritten information can now be captured with the touch of the screen, using common language to improve consistency and legibility. This is accomplished via software configured to the specific requirements of the inspection being conducted. GPS/GIS plays an important role in adding value to these inspections as simple to use touch screen maps allow for operator to simply touch anywhere on the map to provide the location of any discrepancy/item.

In the most basic way, this allows for a GIS coordinate to be attached the item in question to help facilitate the communication and follow-up required to correct the situation. This is referred to as static GIS. That is, the GIS map is geo-referenced and will therefore generate the coordinate once the area is touched with a stylus. It does not require a GPS satellite reception in order to function.

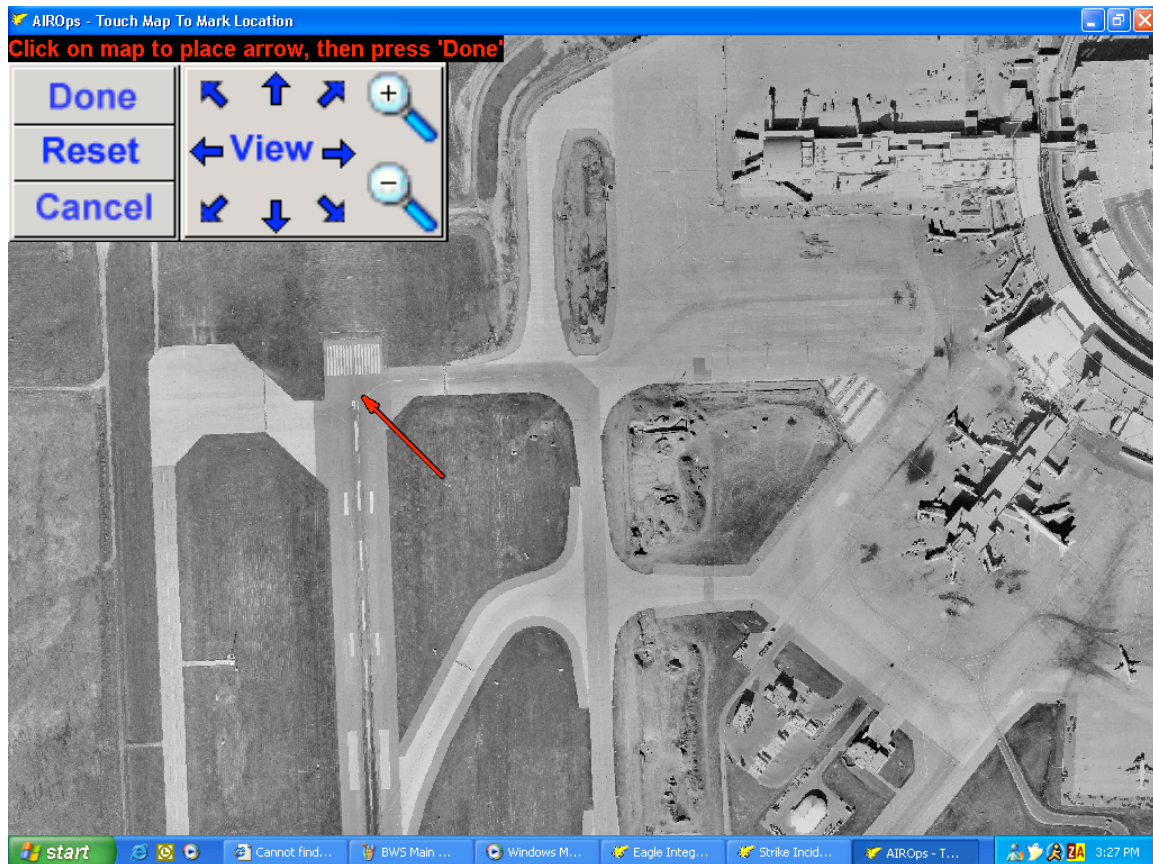


Figure 1. Identifying a location with GPS/GIS

In a much more advanced example, layers of data are applied to the GIS map layer in order to facilitate their interaction with these fixed assets, such as lights, signs and or markings. These electronic CAD layers are typically readily available and provide for the capability to report on an asset-by-asset basis such as an individual light or sign since they occupy a specific location on the earth's surface, always. This allows for data collection over time against the asset and not just against a general location as in the above example. This may be important in more complex environments (Lester B. Pearson International Airport in Toronto has over 14,000 lights) and or in situations where it is desirable to track trends/history on an individual asset basis (El Paso International Airport is doing exactly this).

These layers can also be manipulated/updated by the inspector/user. For example, if there is a light that has been added to the airport infrastructure, but does not appear on the GIS

layer/interface, than this can be added by the user. The user now has the most current, up to date layer with which to interact/report against, and can export this layer to others such as airport engineers who may need this for reference and or master plan update. In a practical sense, this functionality has eliminated the frustration of using stale data for reporting, which increases effectiveness and safety.

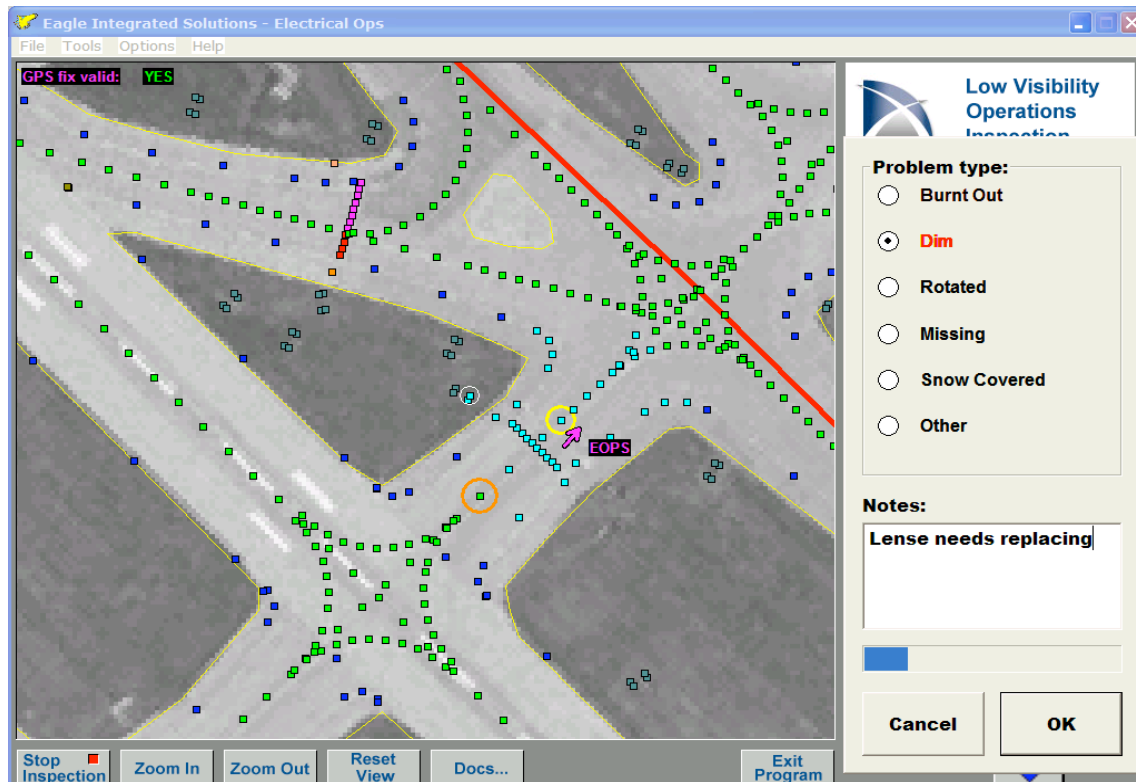


Figure 2. Displaying & interacting with airfield assets (lights here) on the GIS (Toronto-Pearson International Airport)

Real-time data GPS/GIS

There are significant advantages to adding the capability of real-time GPS to the above inspection processes. Consider the example of reporting runway conditions such as friction values and or surface/ambient temperature values.

Most RCR's (Runway Condition Reports) are generated using a paper-based report where critical friction & temperature data has been collected via a continuous friction device or electronic decelerometer. The current process of manually extracting the data from the unit and putting it into a report, electronic or not, leads the operator/inspector to provide subjective data with respect to exactly where the friction values and or temperature values were derived. Consider the advantages of "stamping" the exact location of the friction/temperature data as it is collected by/from the equipment. A very accurate location of the data, which is also date/time initialized is now created. This derives many benefits including the ability to objectively demonstrate due diligence (i.e.

“As you can see, when the plane landed we had friction/Mu values shown via GPS/GIS on the map of 0.6, 0.7 etc. and an average value of .65”). This information now allows for real-time decision making with both economic and environmental benefits (i.e. we only have to anti-ice the touch down area and not the whole runway). Using the GIS interface as a guide, operators can task chemical applicators to apply chemicals at pre-defined rates in predefined areas. This allows for a greater level of confidence in where and how much chemical is applied.



Figure 3. GPS/GIS runway friction measurement

As well, it is now possible as be able to observe trends over time (i.e. the friction values at the high speed exit are deteriorating towards an unacceptable level, so we need to act).

As additional benefits, real-time GPS allows for dramatic improvements to navigation and situational awareness.

Navigation

ARFF teams are required to demonstrate the ability to be anywhere on the airfield to respond to emergencies within minutes. Under ideal weather conditions this may be quite possible. Combine elements such as nighttime, snow/fog/heavy rain and safe, effective navigation can easily be compromised. Real-time GPS/GIS provides the capabilities of giving the position of the vehicle on the airfield surface, so awareness of where the

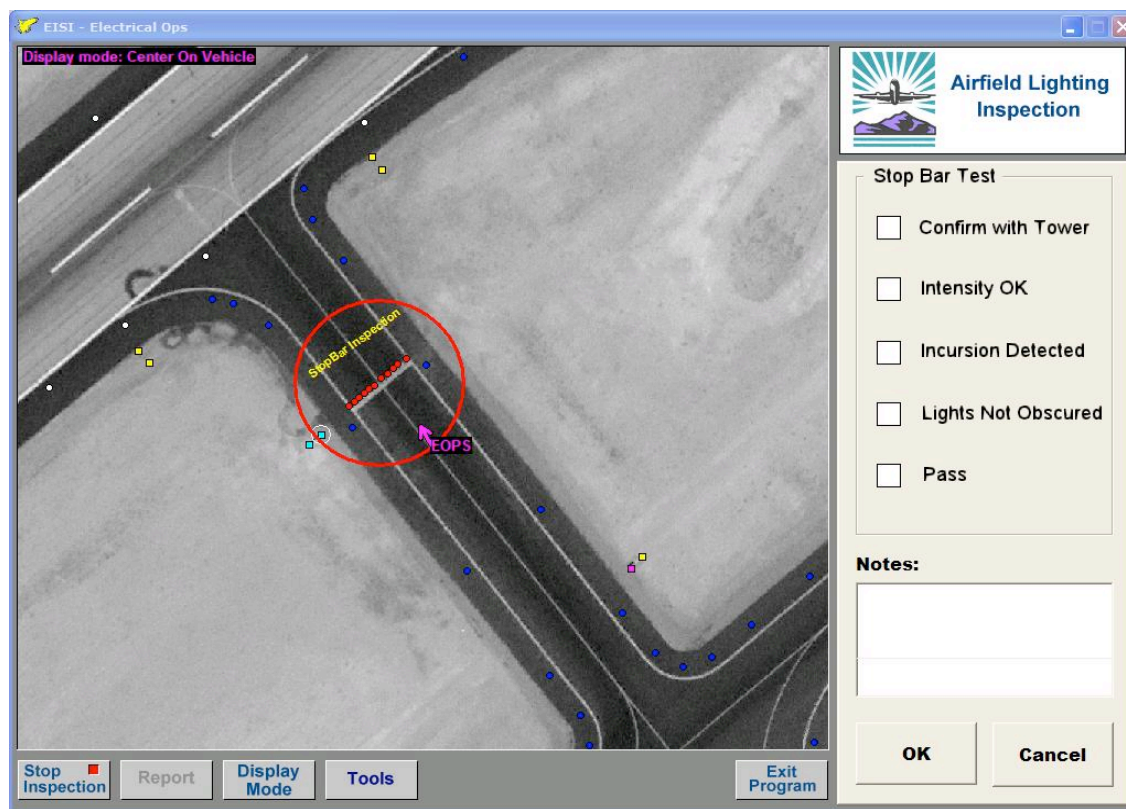
vehicle is in relation to where it needs to be is available. Combine this with instruction on how to get from “A to B”, and you have the capability to drive, watching the progress on the map, while listening to audible commands to help rescue crews get to the incident as quickly as possible. Combining this with the on-board thermal imager provides both the ability to get the required location and see any obstacles in the way. This is a significant improvement from a safety perspective.

In the same fashion, snow teams need to find their way during remarkably difficult and stressful conditions (must get the runway cleared to keep the flow of planes coming in/going out). The lead snow plow/sweeper/blower typically provides the “follow me” capabilities for other equipment. With the ability to see their relative position on the airfield using GPS/GIS, operators can safely and efficiently find their way and guide others if required. Awareness in terms of proximity to fixed assets such as lights and signs can also provide for benefits in terms of less damage/required repair as the operator can avoid these assets during operations (GPS/GIS would allow for the setup of a reminder notification as the operator approached the light they have perhaps hit/damaged in previous snow events).

Lastly, new trainees can benefit by using a predefined route for say a low-vis airfield inspection which will show them where they are relative to the predefined route, warn them if they are going off-track, remind them of how long they should be taking to complete the route and as detailed below, can be reminded if they are approaching safety areas/hot-spots/incursion areas.

Managing Incursions

Because the location, direction and speed of the vehicle is always known via GPS, it is possible to apply conditions or specific rules when certain criteria are met. For example, if an airfield operator is approaching a hold line/stop bar from the non active side, a geo-fence (geographic zone depicted on the map) can be easily (within 10 seconds) set up so that if the operator enters this area, then a message plays/light flashes/horn sounds to warn the operator of the condition that has been met (i.e. flashing yellow light on the dashboard means that you are approaching a hold line). Operators are trained to stop and hold until ATC provides clearance. Other situations such as speeding, approaching another vehicle etc. can also trigger desired responses ahead of time so that the potential for an incident is reduced and or mitigated all together.



**Figure 4. GPS/GIS Incursion warning & Inspection at Stop Bar
(El Paso International Airport)**

Tracking Assets

Inherent to the above is the ability to see where all airfield vehicles are in real-time and historically, from any connected location. This is advantageous in terms of driving efficiency (i.e. the snow team has just left the runway so we can confirm this and give this over to ATC – proactive versus reactive), eliminating waste (GPS allows us to see how long a vehicle has been in the same spot, idling etc.) and driving safety/awareness (El Paso uses real-time GPS to track where their contractors are on a daily basis to determine where they are, where they have been, did they go outside of the area they are designated to operate in etc?)

Historical tracking is useful for incident reconstruction and analysis of efficiency. For example, it might be useful to replay the ARFF vehicle deployment during an incident so we can learn about vehicle/asset management strategy for the next time.

Reporting data/improving communications

GPS/GIS systems operate very well in a stand-alone manner. For example, the lead snowplow may not need to communicate its positional data to anyone else and the functionality of the system for its specific purpose (navigation of the airfield) is perfectly addressed.

There are situations that require collected data to be transferred back to a central location, either immediately and or at some time designated in the future. For example, the ARFF captain may wish to be able to view the location of crews at all times. This requires constant broadcast of data (there are several methods available here). This capability of being able to see where the crews are, and being connected to all assets allows GPS/GIS to drive tremendous advantages in terms of data storage (for use later as described above) and also for communications.

The Calgary Airport Authority utilizes a GPS/GIS System for tracking/engaging with its airside vehicles. Not only are they utilizing the incursion management capabilities described above but are driving ahead with tremendous communications process improvements.

Under certain conditions in Calgary, “Positive Control” (defined between airside operations and ATC, where both parties have certain authorities and responsibilities on the airfield) is engaged. In the past, the communication of this protocol has been by a standard verbal command via radio. This could be somewhat cumbersome and often difficult to ensure that all parties got the order. In the case using GPS/GIS, and where the vehicles are all linked together, it is now possible to send a pre-defined message, using the GIS interface and have visual confirmation that all vehicles received the command. This has driven a higher degree of certainty that people are aware plus significantly reduced radio traffic, keeping lines clear and open for other uses.

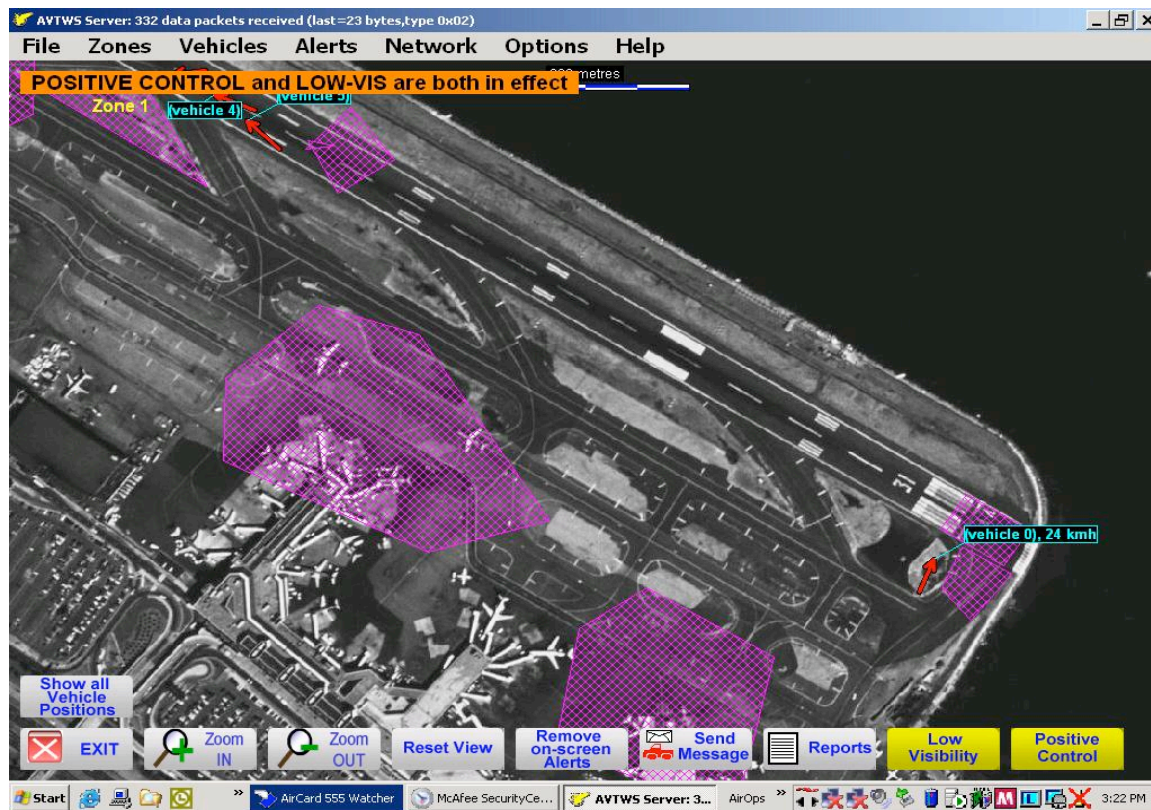


Figure 5. GIS for improving communications

Storing data

No matter what the means of transmitting data back and forth between vehicles, inspectors and a base station, the fact that data is tagged with a GPS coordinate is critical for effective data storage, which in turn drives tremendous reporting capabilities.

Analyzing data

Imagine how long it would take to go through 12 months of daily 139 paper based inspections to determine a visual map of the summation of the years work, for all Bird and Wildlife incidences for example. Conservatively, this might take 8-10 hours.

Data stored in a central database, affixed with a GPS coordinates and the subsequent date, time information, allows a user to simply define the criteria of their specific search and let the GIS system do the work. For example, show “BW sightings, YTD, on taxiway 09/27” would be a very simple request to make, taking less than one or two minutes.

Link to the Maintenance of the airfield (Closing the “loop”)

The ability to collect, store and analyze data is very powerful for the inspection and management aspects of airfield operations, but also can play a significant role in driving efficiencies for maintenance crews. As airports tend to be complex in nature and exposed to elements that can make routine tasks difficult, GPS/GIS driven information provides

clarity for efficient follow up and the ability to easily identify when a discrepancy has been addressed.

For example, airports must deal with the ability to properly communicate the location of a burnt out light. This has been done using traditional paper based maps, spraying the pavement in front of the light with spray-paint and or tying a ribbon around the light in question. All of these methods are subject to either weather (light gets covered in snow etc.) and or communication misinterpretation.

With the inspection methodology described above, GPS/GIS solutions can actually show maintenance crews where they are (their vehicle) in relation to the highlighted discrepancies on the airfield. In this manner, it is virtually impossible to drive to the wrong asset. And once the crew is on-site and have made the repair, they can be given the option to touch the asset in question to identify its status (again this is date & time stamped). The loop is closed.

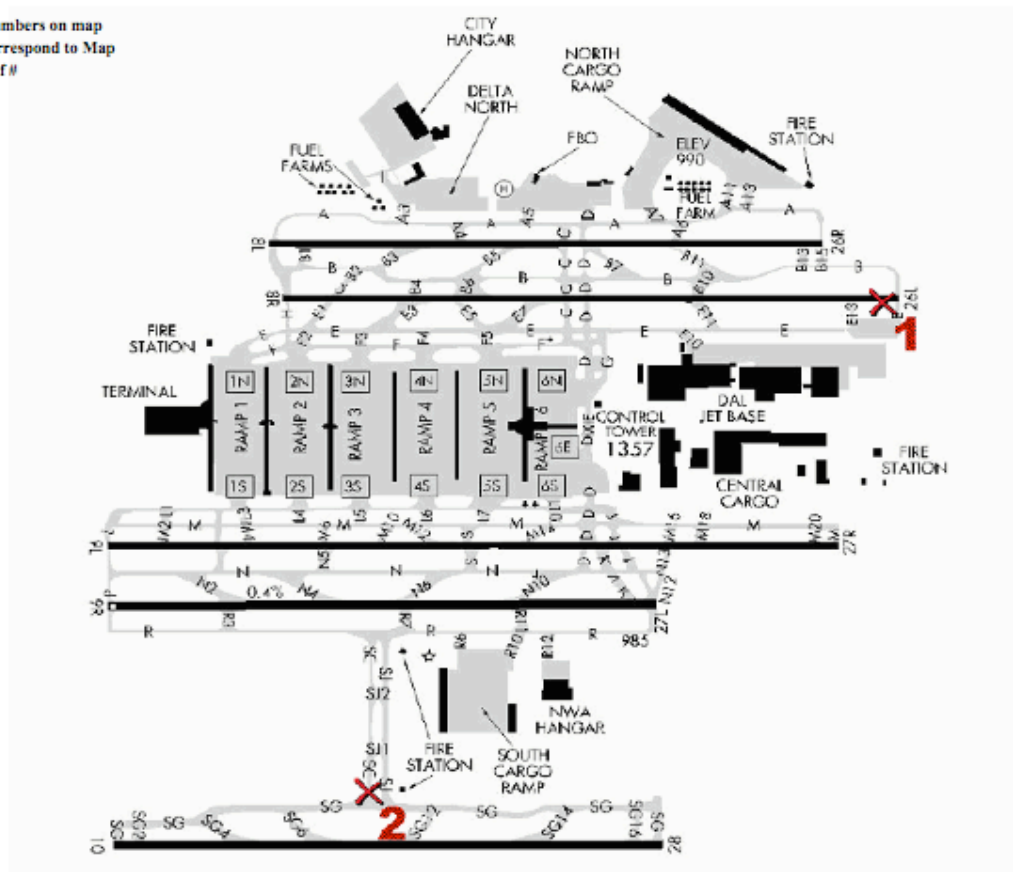
14 CFR Part 139 Problem Summary

Problems - All
 Filtered By: None
 Grouped by: None
 Sorted by: Date

Printed On: Wednesday, March 14, 2007

Map Ref #	Location	Inspector	Discrepancy
Safety Areas (Runway/Taxiway) - 139.309			
1	Ruts/Humps/Depressions/Surface Variations	Paul Cudmore	Damaged
2	Support for ARFF/Snow Vehicles/Aircraft	Paul Cudmore	FOD

Numbers on map
 correspond to Map
 Ref #



Summary

GPS/GIS solutions are scalable in nature, which is important with respect to the value they can create for an airport, as each one is unique in terms of operational challenges, available budget, human resources etc. Good programs will allow airport operators to build on this technology over time, starting with their most pressing needs (for example, getting a handle on incursions) and adding to this over time, to perhaps include a common inspection platform, while never dictating processes and or reporting output as this should be customizable.

GPS/GIS solutions are intuitive and easy to use, making adoption relatively simple as the information/user interface is typically packaged in a familiar format (i.e. the high resolution image of the airfield is the backdrop).

Lastly, while GPS/GIS solutions offer obvious opportunities for airport operations, it is important that these technologies (and others for that matter) are used as support tools rather than being considered replacement solutions. They can help make well-documented processes more efficient and well-trained staff safer, but they cannot replace the need to continue to provide sound processes and proper training for airport operators.

References:

- 1) Flight Safety Foundation: Web articles, 2007.
- 2) Console, Sam. Comments from discussion, 2007.

Special thanks to:

- 1) Jerry Bettendorf- El Paso International Airport
- 2) Dwayne Kowalski- Calgary Airport Authority
- 3) Sam Console- Philadelphia International Airport
- 4) Robert Gentile- Toronto Pearson International Airport

Appendix #1:**What is GPS?**

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day. There are no subscription fees or setup charges to use GPS.

How it works.

GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map.

A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude). Once the user's position has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more.

How accurate is GPS?

Today's GPS receivers are extremely accurate, thanks to their parallel multi-channel design. 12 parallel channel receivers are quick to lock onto satellites when first turned on and they maintain strong locks, even in dense foliage or urban settings with tall buildings. Certain atmospheric factors and other sources of error can affect the accuracy of GPS receivers. Most GPS receivers are accurate to within 15 meters on average.

Newer GPS receivers with [WAAS](#) (Wide Area Augmentation System) capability can improve accuracy to less than three meters on average. No additional equipment or fees

are required to take advantage of WAAS. Users can also get better accuracy with Differential GPS (DGPS), which corrects GPS signals to within an average of three to five meters. The U.S. Coast Guard operates the most common DGPS correction service. This system consists of a network of towers that receive GPS signals and transmit a corrected signal by beacon transmitters. In order to get the corrected signal, users must have a differential beacon receiver and beacon antenna in addition to their GPS.

The GPS satellite system

The 24 satellites that make up the GPS space segment are orbiting the earth about 12,000 miles above us. They are constantly moving, making two complete orbits in less than 24 hours. These satellites are traveling at speeds of roughly 7,000 miles an hour.

GPS satellites are powered by solar energy. They have backup batteries onboard to keep them running in the event of a solar eclipse, when there's no solar power. Small rocket boosters on each satellite keep them flying in the correct path.

Here are some other interesting facts about the GPS satellites (also called NAVSTAR, the official U.S. Department of Defense name for GPS):

1. The first GPS satellite was launched in 1978.
2. A full constellation of 24 satellites was achieved in 1994.
3. Each satellite is built to last about 10 years. Replacements are constantly being built and launched into orbit.
4. A GPS satellite weighs approximately 2,000 pounds and is about 17 feet across with the solar panels extended.
5. Transmitter power is only 50 watts or less.

What's the signal?

GPS satellites transmit two low power radio signals, designated L1 and L2. Civilian GPS uses the L1 frequency of 1575.42 MHz in the UHF band. The signals travel by line of sight, meaning they will pass through clouds, glass and plastic but will not go through most solid objects such as buildings and mountains.

A GPS signal contains three different bits of information — a pseudorandom code, ephemeris data and almanac data. The pseudorandom code is simply an I.D. code that identifies which satellite is transmitting information. You can view this number on the GPS unit's satellite page, as it identifies which satellites it's receiving.

Ephemeris data tells the GPS receiver where each GPS satellite should be at any time throughout the day. Each satellite transmits ephemeris data showing the orbital information for that satellite and for every other satellite in the system.

Almanac data, which is constantly transmitted by each satellite, contains important information about the status of the satellite (healthy or unhealthy), current date and time. This part of the signal is essential for determining a position.

Source: www.garmin.com

What is a GIS?

A GIS is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information; that is, data identified according to location. Practitioners also define a GIS as including the procedures, operating personnel, and spatial data that go into the system.

How does a GIS work?

Relating information from different sources

The power of a GIS comes from the ability to relate different information in a spatial context and to reach a conclusion about this relationship. Most of the information we have about our world contains a location reference, placing that information at some point on the globe. When rainfall information is collected, it is important to know where the rainfall is located. This is done by using a location reference system, such as longitude and latitude, and perhaps elevation. Comparing the rainfall information with other information, such as the location of marshes across the landscape, may show that certain marshes receive little rainfall. This fact may indicate that these marshes are likely to dry up, and this inference can help us make the most appropriate decisions about how humans should interact with the marsh. A GIS, therefore, can reveal important new information that leads to better decision-making.

Source: www.usgs.gov